# 611-0110 (40-350) Second Law of Motion Apparatus

## Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

## Description:

This apparatus uses two (2) balls travelling unequal distances at unequal rates of acceleration to demonstrate a special case of Newton's Second Law of Motion.

**Newton's Second Law** pertains to unbalanced forces. It can be defined as: *the change of motion in a body is proportional to the force applied and occurs in the direction of the line of action of the applied force.* When more than one direction of force is applied, the acceleration of a body is directly proportional to the resultant force acting upon it.

The Second Law of Motion Apparatus illustrates independence of motion, a special case involving a superimposed force, which is a force that acts on a body independently. It demonstrates that if two (2) balls are positioned so that one is projected forward horizontally while the other drops vertically under the force of gravity, both strike the floor at the same time, despite the fact that they are traveling unequal distances at unequal rates.

## Operation:

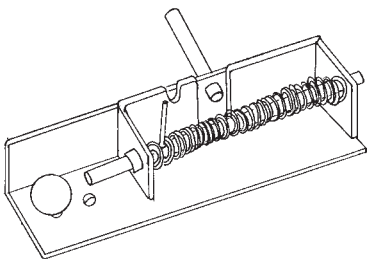
This apparatus may be used with a ring stand or clamped to a table. Make sure it is level.

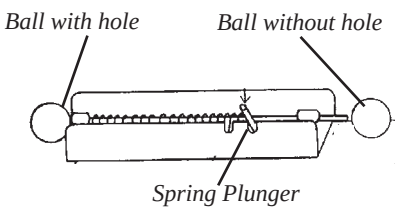
**To use with ring stand:** Use ring stand shaft protruding from base to attach to ring stand.

**To use without the ring stand:** Place apparatus at an angle over the corner of a table so both ends project into open space, so that balls can fall unimpeded. Apparatus may be clamped with C-clamp or held down with your thumb.

Position balls at either end. Take spring plunger handle and move plunger forward until handle slips into a notch. Four holes in base are now exposed. Place solid ball over one of four holes on base, which serve to keep ball in place. Insert ball with hole onto end of shaft. Release spring plunger handle. Watch path of both balls as they fall to floor. When does each ball strike the floor?

You instinctively expect the two balls to strike the floor at different times. However, they should strike at exactly the same instant. If not, your apparatus was probably not level.






## Theory:

*Diagram 2* illustrates the paths of motion taken by both balls. When released at the same moment by the action of a trigger or plunger, one of the balls is given a horizontal motion perpendicular to the force of gravity and thus independent of gravity, while the other is acted upon solely by the force of gravity.

Since both balls fall through the same vertical distance in the same time interval, however, this is a demonstration of independence of motion.

The projected motion - the horizontal motion caused by the plunger 0- is superimposed over other forces that act on a body and act independently of them. In this case, the horizontal motion of the solid steel ball is independent of the downward motion imparted to it by the acceleration of gravity.

The balls must strike the floor at the same time since each ball has the same downward velocity (zero) and each was acted upon by the same force (gravity.)

Please note that this special condition holds only when the horizontal motion is truly horizontal. If the Second Law of Motion Apparatus were tilted either up or down, a vertical component of motion would be added to the path taken by each ball, and the vertical distances and time intervals of each would no longer be equal.

Independence of motion can be proved mathematically using the Trigonometric Laws of Sines and Cosines. By definition, X (the horizontal component) and Y (the vertical component) are written as follows:

**X = B Cos** θ

**Y = B Sin** θ**Where B represent the force in question and** θ **represent the angle.**

Since θ is zero (0) if the force is

horizontal and 90 if the force is perpendicular,

**X = B (Cos θ)**
**= B (1)**
**= B**

Where B represents the force in question and θ represents the angle.

Since 0 is zero (0) if the force is horizontal and 90 if the force is perpendicular,

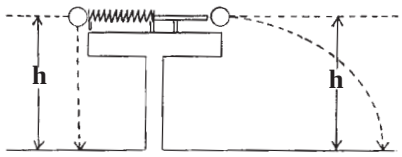
**X = B Cos (0)**
**= B (1)**
**= B**

and

**Y = B Sin (90°)**
**= B (1)**
**= B**

In this example, X represents the ball with horizontal projectile motion and Y represents the ball acted upon solely by the force of gravity. The force (B) for both is therefore seen to be equal.

*Diagram 2*




## How to Teach with Second Law of Motion Apparatus:

**Concepts Taught:** Change of velocity (acceleration); effect of force (F = ma). Newton's Second Law. Force and velocity as directed (vector) quantities. Resultant force; resultant acceleration. Acceleration due to gravity. Time of fall under gravity independent of horizontal force on a body.

**Curriculum Fit:** Physics Sequence/ Motion and Force. *Causes of Motion.* **Grade 9-10.**

## Related Products:

**Science First®** *manufactures many low-cost science labs which are carried by most science education dealers.*

**611-2350 Free-Fall Tube-** Show how heavy and light items fall at the same rate in a vacuum. Duplicate Galileo's experiment. Includes: butyrate tube with capped ends; hose cock and hose; instructions.

**611-1220 Variable Inertia -** Instantly change distribution of mass with 8 balls inserted into your choice of compartments. Load each of 2 discs unevenly, roll together down an incline. Which is faster, with the mass toward the center or toward the rim? Why? *Includes:* 8 steel balls, 2 discs with hardware, instructions.

**611-1340 Acceleration Trolley -** Show how the rate of acceleration of an object depends upon the angle of incline. Features 2 low friction pulleys with holes to attach weights, brackets to place trolley anywhere along the wire. *Includes: trolley* with pulley; 1.5 m wire cable; attachment kit with hardware; instructions.

**611-1830 Gyroscope -** Explore the mysteries of inertial guidance, precision gyroscope compasses and stabilization. Features dynamically balanced 6 cm rotor, frictionless teflon bearings. *Includes:* base, rocker with gimbal cradle, pull cord, weights and hook, instructions

**652-1010 Anemometer -** This colorful working model is sensitive to breezes as slight as 2 mph. Determine wind speed by counting the rotations. 4 molded plastic cups, one red for contrast; cone bearing hub; axle; base; instructions

**611-0350 Roman Arch -** A working model of an architectural marvel - will even support your weight without glue or mortar. Build it without the template first - a geometric puzzle. 23 precision cut hardwood blocks in 6 unique shapes, drilled base, buttresses, hardware, instructions.

**611-1300 Mini Dynamics -** Colorful system lets you experiment affordably with elastic and inelastic collisions. Plastic cars have bumpers that attach with screw, deep wells for weights, low friction wheels that snap into place. Includes 2 plastic cars, 2 bumpers with hardware, 2 rubber stoppers, instructions.

**611-0035 Inclined Plane -** Solid aluminum inclined plane and full range of accessories. Investigate acceleration, friction and gravity; duplicate Galileo's free-fall experiments. Folds for storage, clamps up to 45°, features removable protractor with scale and low-friction pulley.

**611-1215 Ring and Disc -** Simple materials with same mass and diameter- PVC ring and hardwood disc - demonstrate how mass is distributed in rolling bodies. Roll together down incline, study difference in acceleration. Instructions.

**May we suggest:**

**611-1710 Collision In Two Dimension:** Study how energy and momentum change in elastic and inelastic collisions. This apparatus consists of a curved track with a base at one end. One the base is a support to hold a ball at the proper height for a center to center collision with a second ball rolling down the track. The track is level so collision occurs only the horizontal plane, simplifying calculations. Includes: 45" one-piece track; 3 balls (1"/2.54 cm diameter) - 2 steel, 1 glass; mount; hardware; instructions.

## P/N 24-0350